C. BAUKAL, B. WEIMER, M. PAPPE,
J. MCGUIRE, B. JOHNSON and R. LUGINBILL,
John Zink Hamworthy Combustion, Tulsa, Oklahoma

Good, bad and ugly process burner flames

As part of the U.S. Environmental Protection Agency's (EPA's) maximum achievable control technology (MACT) fired heater inspection program, the authors' company has inspected nearly 1,000 heaters since the program started in 2015. These inspections have revealed all types of flames—the good, bad and ugly. Here, good is defined as no changes are needed; bad is defined as changes are needed where the conditions are not likely dangerous; and ugly is defined as immediate changes are needed because the conditions are potentially dangerous.

Judging flame quality is somewhat subjective, as no instrument exists to measure it. However, some basic principles can be used to determine the conditions of flames. Given the number of bad and ugly flames observed on a regular basis, these principles are apparently either not universally known or are not being used to correct flame problems.

FIG. 1. Examples of good flames.

FIG. 2. Air registers improperly closed, views (A) inside the heater and (B) outside the heater.

Good flames.

Perhaps the most important principle of good flames is stability. While no stability meter exists now, some instabilities are easy to recognize. For example, flames should not be pulsing or bouncing, often called *huffing*. A lifted flame is defined by a significant gap between the outlet of the burner and the start of the flame. A flame can be lifted without bouncing, which is also undesirable and potentially dangerous. Good flames are steady and anchored near the burner outlet.

Some factors should be observed to determine whether a flame is good or not. Most fired heaters have multiple burners, so another principle is uniformity: all flames should look approximately the same. While there are occasionally exceptions to that rule, they are generally rare.

Another principle is that flames should be the appropriate color; this depends on the fuel composition, the burner design and the operating conditions. For example, firing liquid fuels, such as light or heavy oils, normally produce more yellow flames because the high concentration of carbon in the fuel initially produces soot in the flame, which produces luminosity that appears yellow to our eyes based on the flame temperatures. On the other extreme is hydrogen (H_2), which has no carbon to produce soot and therefore appears to be blue. Older burners may produce more yellow flames when burning heavier hydrocarbons, while newer burners generally produce flames that tend to be blue, regardless of the fuel composition, due to their more uniform temperature.

An indirect measure of good flames is the temperature uniformity of the burner tiles. There should be no pronounced hot spots or dark spots that can indicate a problem with the fuel injectors (tips). The tips might be plugged, improperly oriented or possibly the incorrect ones.

Good flames should be distinct from

each other and not leaning into each other or into process tubes. Some examples of good flames are shown in **FIG. 1.**

Bad flames. Bad flames may be non-uniform, have poor flame patterns or improper colors, produce significant hot spots or dark spots on the burner tiles, or be leaning into each other or into the furnace walls, roof or floor. While these are usually not dangerous conditions, they typically adversely affect heater operations and can lead to significant problems if not corrected. They may reduce the heater efficiency and/or increase pollution emissions.

FIG. 2 shows burner air registers that are improperly set, one inside (**FIG 2A**) the heater and one outside (**FIG. 2B**) the heater. Two of the registers were closed to achieve the target excess oxygen (O_2), but air registers should normally all be adjusted to the same settings. Not enough air is going through the burners with the closed air registers, which makes their flames yellow. Too much air is going through the only burner of the three with the air register open, which makes the flame more blue. While this is not a dangerous condition, it clearly does not produce the desired heat flux profile and could produce higher air pollution emissions.

FIG. 3 shows that when some fuel injectors are more plugged, they can force more fuel to the injectors that are cleaner. In the lower burner, no flames are visible where the tips are heavily plugged. In the top burner in **FIG. 3,** the flames with the yellow tips are the cleanest and are allowing more fuel to flow than designed.

The dramatic impact the heater draft and excess O_2 have on heater operation is shown in **FIG. 4.** In **FIG. 4A,** the flames are long and lazy and the firebox is dark. In **FIG. 4B,** the flames are short and properly firing across the floor where the heater is much brighter. The ugly flames in **FIG. 4A** were corrected by properly adjusting the draft and the excess O_2.

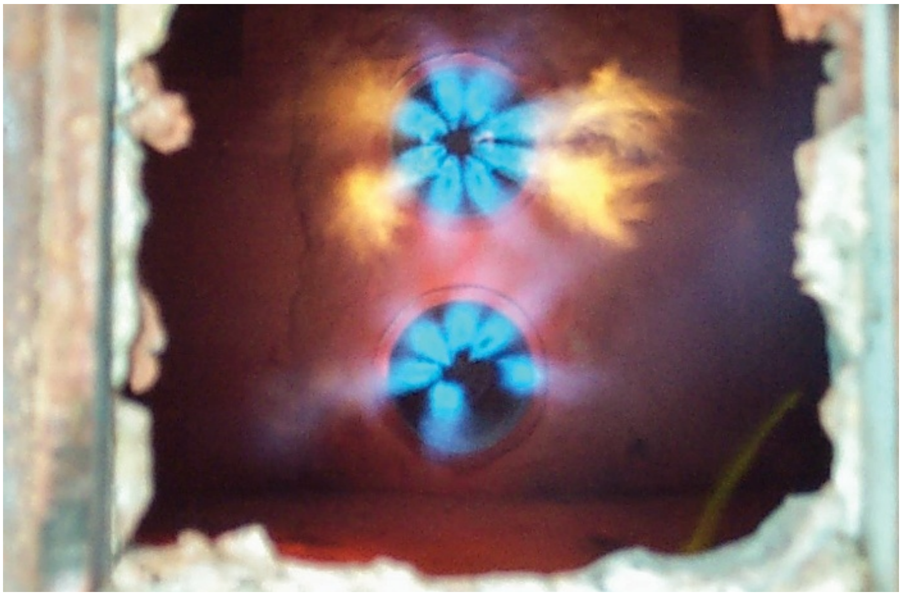

FIG. 3. The bottom burner has some plugged tips, forcing more gas to the top burner.

FIG. 4. Flat flame burners firing along the floor (A) before adjusting the excess O_2 and draft and (B) after adjustment.

Ugly flames. Ugly flames may be unstable, severely lacking oxygen for combustion, or impinging on process tubes. Unstable flames (e.g., flames that are pulsing or lifted, as shown in **FIG. 5**) can flame out and then be reignited a short time later in a hot furnace, which can cause an explosion.

Another condition that can produce ugly flames is prolonged flame impingement. This can cause process tubes to overheat and produce a layer of coke inside the tubes that reduces the convective cooling effect and further exacerbates the overheating problem. This can eventually lead to a tube leak or rupture.

Takeaway. Process burners must be properly designed, installed, operated and maintained so that they produce good flames. Burners and heaters must be frequently inspected to detect problems before process flames become bad or even ugly. Flames should be uniform and not lifted, be the proper color and flame pattern (e.g., no impingement, not too long, no leaning), have no pronounced hots spots or dark spots on the burner tiles, have no irregular flame movement (such as pulsing) and make no unusual sounds, such as from flashback.

The objective of good heater operation is not to have perfect flames, as that is unlikely. However, the quality of some flames may be so poor as to be classified as bad or, even worse, as ugly. Both types should be avoided and if detected, be corrected as soon as possible. Ugly flames may be potentially dangerous and may require correction from some distance from the heater. Ideally, diligent attention to proper burner operation and maintenance will help avoid ugly flames. HP

CHUCK BAUKAL is the Director of the John Zink Institute, part of John Zink Hamworthy Combustion, where he has been since 1998. Dr. Baukal is the author/editor of 13 books on industrial combustion, including the *John Zink Hamworthy Combustion Handbook.*

BILL WEIMER joined John Zink Hamworthy Combustion in 2012 as Turnaround Manager and Regional Customer Advisor. He has more than 45 yr of industry experience, and previously worked for ExxonMobil in operations, technical service, and in various roles ranging from first line supervisor to manager.

MIKE PAPPE has been with John Zink Hamworthy Combustion for 29 yr and is part of the Customer Support Solutions group. He is involved in commissioning, startup and training of fired equipment in refineries. He is a co-author of several articles on industrial burners and chapters in the *John Zink Hamworthy Combustion Handbook.*

JOHN MCGUIRE joined John Zink Hamworthy Combustion in 1988 and is part of the Customer Support Solutions group. He is a Qualified PHAST Specialist and is a subject matter expert in burners, flares and thermal oxidizers, including assembly, installation and operation. Mr. McGuire is an instructor for the John Zink Institute and has co-authored many publications.

BILL JOHNSON provides technical support for the Customer Support Solutions group at John Zink Hamworthy Combustion, where he has worked since 1977. He has been an instructor for the John Zink Institute for more than 35 yr. Mr. Johnson has co-authored numerous technical papers for the HCPI industry and is the lead author on several chapters in The *John Zink Hamworthy Combustion Handbook.*

ROBERT LUGINBILL has been at John Zink Hamworthy Combustion since 1992 and is part of the Customer Support Solutions group. He has more than 35 yr of industry experience and many certifications. His areas of expertise include fired heater operations, troubleshooting and inspections.

FIG. 5. Examples of pulsing/lifted flames.